IOTA Simulation Model Description

The algorithms of the simulation model are based on Jordan Murkin's work[1]. The model is implemented by Joon Park and updated/maintained by Dr. Anastasia Angelopoulou. The works of Jordan Murkin and Joon Park are supervised by Dr. Ruzanna Chitchyan. This work is supported by the UK EPSRC funding for Refactoring Energy Systems (EP/R007373/1) and Household Supplier Energy Market (EP/P031838/1) projects.

1. Purpose

The purpose of the model is to simulate a P2P energy trading market on the IOTA DAG-Based distributed ledger and investigate whether such a market would be feasible on this ledger with respect to transaction confirmation time and number of transactions.

2. Entities, State variables and scales

The model consists of two entities: Buyers and Sellers. Each entity is characterized by the state variables (Table 1): id, location, amount of electricity to sell or buy, generation type (as a priority list, ranked from 1 to 5), distance preference (how far he/she wants to sell to or buy from), the price preference (price range willing to sell or buy), and rating. In order for a transaction to occur, the seller's rating must be greater than the consumer's minimum rating required. The rating is used to improve the transaction quality.

Table 1. Agent Structure

Properties	Definition
Agent ID	Unique agent identifier
Agent location	Agent location in two dimensional continuous space (as latitude and longitude)
Amount of electricity	Amount of electricity to buy or sell for every trading period (generation/consumption)
Generation Type	Generation type (i.e., solar PV, wind, anaerobic digestion, hydro, and micro CHP)
Distance preference	Distance preference for the trade
Price preference	Minimum price willing to sell for seller agent or maximum

[1] Murkin, J., Chitchyan, R., Ferguson, D.: Goal-Based Automation of Peer-to-Peer Electricity Trading. In: From Science to Society, pp. 139-151 (2018)

	price willing to buy for buyer agent
Rating	Indicates the rating required for a transaction to occur.

The environment consists of the IOTA (Tangle), which is a DAG-based distributed ledger. In this data structure, one vertex represents one transaction. Each transaction node in the Tangle has a name, a buyer ID, a seller ID, the amount of energy exchanged, the unit price, the time that the transaction took place, the confirmation time and a cumulative weight. New transaction selects the tips to validate based on one of three tip-selection algorithms:

- Uniform random selection algorithm, whereby each participating node in the network uses uniform random selection method to choose two tips to confirm
- Unweighted random walk algorithm, whereby starting from the genesis node, the walker chooses which transaction to move to with equal probability
- Weighted random walk where each transaction is assigned a weight and a cumulative weight. Weight defines how much work has been invested into each transaction by the issuing node. Cumulative weight is the sum of the weights of the given transaction and all other transactions that directly or indirectly reference the given one.Under the weighted random walk selection algorithm, a validating node selects a tip based on tip's weight.

3. Process overview and scheduling

The model proceeds in trading period steps. In the period-based trading, the trading is carried out on every t (where t can be 30 min, or less) period. During each period, the trading algorithm steps are processed in the following order:

- The sellers post their sales information and preferences.
- The buyers post their purchase information and preferences.
- Each buyer is assigned to each seller, and a score for each buyer-seller pair is calculated.
- The score from the buyer-seller combination is then used in the rank order in the market, and the buyer-seller pair with the highest score is matched.
- The transaction takes place and transaction information is recorded in the distributed ledger.

4. Design Concepts

Interaction: Interactions between agents are divided into direct and indirect interactions. In direct interactions, agents change each other’s states through behavioral functions defined in different agents. Examples of direct interactions include transactions and communication between agents. Indirect interactions affect other agents by influencing

the environment (e.g., setting preferences for trading).

Stochasticity: All state variables and parameters are interpreted as probabilities.

Observation: For model testing, the average distance and number of trades were observed in each period. For model analysis, DAG-related variables were recorded over time, i.e. average degree of DAG, average confirmation time, shape of the DAG (using the GraphViz tool), and average number of tips (unconfirmed transactions).

5. Initialization

A percentage of the accounts were assigned to be sellers. Simulations were run for 16 replications, where the percentage of sellers in the market ranged from 5% to 20% in 5% increments, and the number of participants ranged from 500 to 3000 in increments of 500.

6. Input

Before the model could be executed, it needs to be set up (Table 2). Here the accounts were randomly generated for each simulation. We assume buyers and seller of the p2p electricity market area located in an arbitrary area in the UK, with latitude randomly chosen between 50.956870 and 52.438562, and longitude between -2.386779 and 0.292914. Sellers' generation types are uniformly distributed, and sellers generate from 5 to 10 kWh every trading period. Five types of generation are used: solar, wind, hydro, anaerobic digestion, and micro CHP. Distance preference was set for all accounts between 5-10km. For buyers, the maximum price to buy is set randomly between 14p and 16p per kWh, and the demand is set randomly between 1 kWh and 6 kWh. Each of these state variables is generated from a uniform distribution. Buyers' and sellers generation-type preferences are set randomly. The generation-type preference is modeled as a priority list, ranked from 1 to 5. A percentage of the accounts were assigned to be sellers.

Table 2. Simulation Input

Properties	Definition
Agent location	Latitude: [50.956870, 52.438562] Longitude:[-2.386779, 0.292914]
Sellers' generation	5-10kW per trading period
Generation Type	solar, wind, hydro, anaerobic digestion, micro CHP
Distance preference	5-10 km
Demand	1-6 kWh
Buyer's max price preference	14-16p/kWh
Number of participants	500 to 3000 in increments of 500

7. Output

The results of the simulation are exported in the "output.txt", "executionTime.txt", and in the text files in the folders "tangle_confirm" and "tangle_result". The GraphViz tool (https://www.graphviz.org/) can be used to open the “result_period_<number.”.txt and visualize the shape of the tangle for each period. The average degree of DAG, average confirmation time, and average number of tips (unconfirmed transactions), average number of trades and average trade distance over time are displayed within the model’s Main view (Fig. 1).

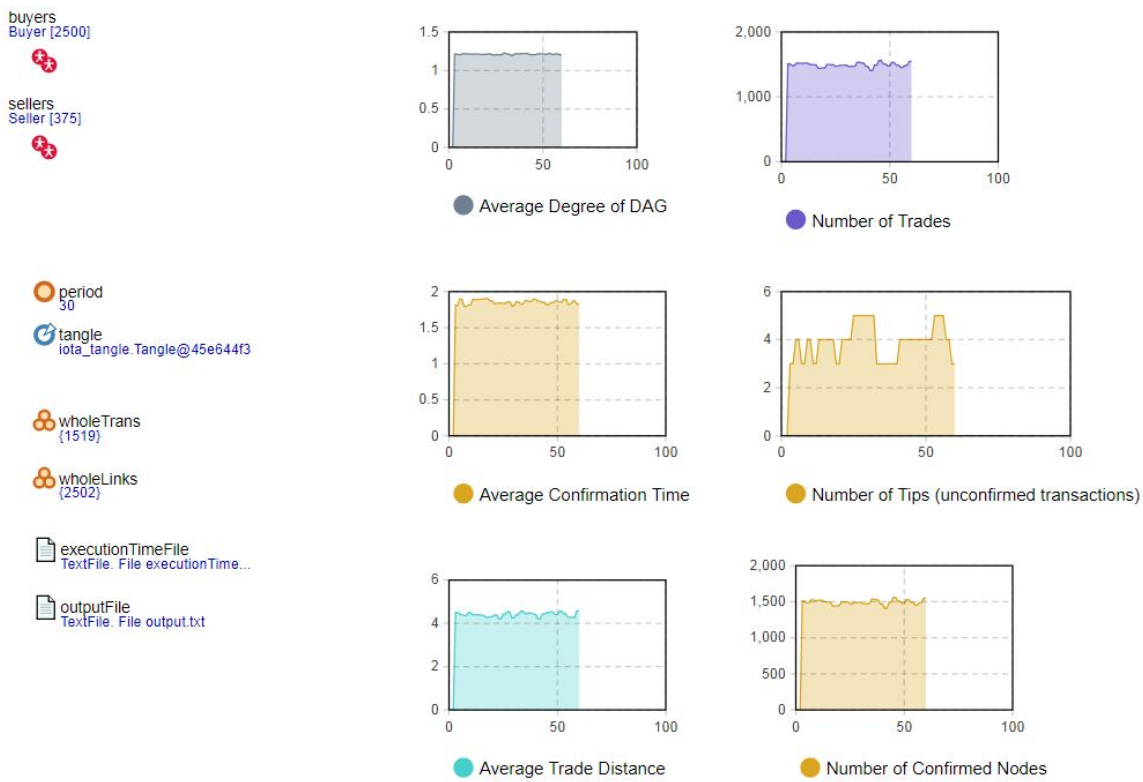

Figure 1: Simulation Output for 2500 buyers and 375 sellers

8. User Interface

The following user interface (Fig. 2) is provided to allow user to change the model parameters. The user can change the number of buyers and sellers, the tip selection algorithm, and the minimum and maximum delay for releasing the transactions. If the

weighted random walk tip selection algorithm is chosen, the user can change the value of alpha. Alpha affects the level of randomness in the random walk.

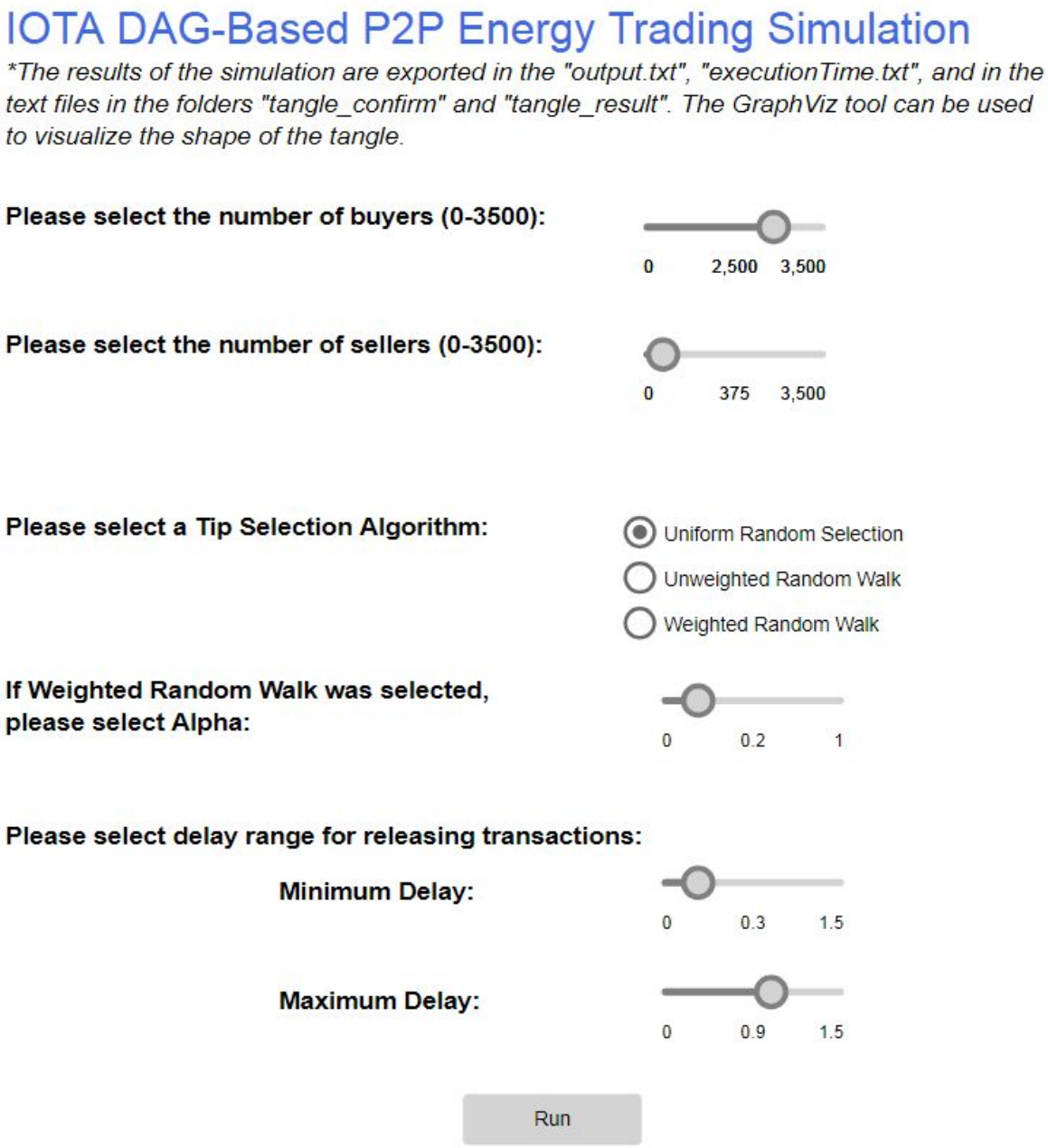

Figure 2: User interface that allows changing the model's parameters